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Virtual surgical planning in oral and maxillofacial surgery and traumatology: evolution, clinical applications, and integration of artificial intelligence.

Virtual surgical planning in oral and maxillofacial surgery: evolution, clinical applications and the integration of artificial intelligence

Virtual surgical planning in oral and maxillofacial surgery and traumatology: evolution, clinical applications and integration of artificial intelligence

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Summary

The incorporation of digital technologies has profoundly modified the planning and execution of procedures in Oral and Maxillofacial Surgery. The combination of computed tomography, virtual surgical planning, CAD/CAM systems, additive manufacturing, and, more recently, artificial intelligence-based tools, has expanded the capacity for individualizing treatment and favored greater predictability in different surgical approaches. These technologies have come to play a relevant role in the management of dentofacial deformities, complex traumas, craniofacial reconstructions, and implant-supported rehabilitations, allowing the integration of anatomical, functional, and prosthetic data into a single digital workflow.

Although technological advancements are evident, their incorporation into clinical practice must be critically analyzed. Much of the available evidence demonstrates benefits related to the precision of planning, the reproducibility of procedures, and the reduction of intraoperative steps. However, challenges persist associated with the clinical validation of artificial intelligence algorithms, the methodological standardization of studies, implementation costs, and the need for specialized training of teams.

This article presents a narrative review of the evolution of virtual surgical planning in Oral and Maxillofacial Surgery, discussing the technological foundations that underpin its clinical application, the main evidence available in the literature, and the emerging role of artificial intelligence as a tool to support surgical planning. It also addresses the current limitations of these technologies, their ethical and regulatory aspects, and the prospects for their progressive incorporation into evidence-based clinical practice.

Keywords: Oral and Maxillofacial Surgery and Traumatology. Virtual surgical planning. Artificial intelligence. CAD/CAM. Three-dimensional printing.

Abstract

The incorporation of digital technologies has profoundly transformed planning and execution in Oral and Maxillofacial Surgery. The integration of computed tomography, virtual surgical planning, CAD/CAM systems, additive manufacturing, and more recently artificial intelligence-based tools has improved treatment individualization and enhanced predictability across a wide range of surgical procedures. These technologies have become increasingly relevant in the management of dentofacial deformities, complex facial trauma, craniofacial reconstruction, and implant-supported rehabilitation by integrating anatomical, functional, and prosthetic information into a unified digital workflow.

Despite these advances, the clinical adoption of digital technologies requires critical evaluation. Current evidence consistently demonstrates improvements in planning accuracy, surgical reproducibility, and optimization of intraoperative workflow. However, important challenges remain regarding external validation of artificial intelligence algorithms, methodological heterogeneity

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among published studies, implementation costs, and the need for specialized professional training. This narrative review discusses the evolution of virtual surgical planning in Oral and Maxillofacial Surgery, highlighting its technological foundations, current clinical applications, scientific evidence, and the emerging role of artificial intelligence as a decision-support tool. Current limitations, ethical considerations, and future perspectives for evidence-based clinical implementation are also discussed.
Keywords: Oral and Maxillofacial Surgery. Virtual Surgical Planning. Artificial Intelligence. CAD/CAM. Three-dimensional printing.

1 INTRODUCTION

The digital transformation observed in the health sciences in recent decades has changed the way...
The planning and execution of highly complex surgical procedures is significant.
Oral and Maxillofacial Surgery and Traumatology: this evolution was driven primarily by
development of advanced image acquisition methods, reconstruction software
three-dimensional, *computer-aided design (CAD)* systems
Computer-Aided Manufacturing (CAM) and technologies
Additive manufacturing. The integration of these resources has made it possible to replace some conventional methods.
digital workflow planning capable of representing the anatomy of more accurately
patient and anticipate different stages of the surgical procedure (MILORO et al., 2022; FONSECA, 2018).

For much of the 20th century, surgical planning in Surgery and Traumatology
Oral and maxillofacial surgery relied on two-dimensional radiographs, plaster models, and tracings.
Cephalometric measurements and clinical evaluation. Although these methods have contributed decisively to the
While the consolidation of the specialty had limitations related to three-dimensional representation, it also presented limitations.
of craniofacial structures, especially in cases involving dentoskeletal deformities
complex, extensive mandibular reconstructions and high-energy facial trauma (ELLIS III; GHALI; LARSEN; WAITE, 2012; FONSECA, 2018).

The introduction of computed tomography and, subsequently, computed tomography of
Cone *beam computed tomography (CBCT)* represented an important milestone in this...
evolutionary process. The possibility of three-dimensional reconstruction of bone structures favored
A greater understanding of the individual anatomy of patients created the basis for the development of
Virtual surgical planning *(VSP),* currently employed in
different areas of the specialty, including orthognathic surgery, facial traumatology, reconstruction
craniofacial, advanced implantology and microvascular reconstructive surgery (JOACHIM; MILORO, 2025).

In recent years, the incorporation of artificial intelligence has expanded the possibilities of workflow.

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digital. Machine learning and deep learning algorithms have been used for
Automate image segmentation, identify anatomical structures, and assist in the creation of...
Three-dimensional models and optimize pre-operative planning steps. Although these applications
Although they present promising results, the literature shows that their clinical use still depends
of robust scientific validation, especially regarding reproducibility and generalizability of
algorithms and their impact on relevant clinical outcomes (DANG et al., 2025).
Unlike interpretations frequently disseminated in technology publications,
Artificial intelligence does not represent a replacement for clinical judgment. Its current role
It focuses on supporting decision-making by automating repetitive tasks and increasing efficiency.
of information processing. The definition of the surgical strategy, the interpretation of
Anatomical characteristics and the conduct of treatment remain the responsibility of
surgeon, whose experience remains crucial for achieving predictable results and
biologically safe (JOACHIM; MILORO, 2025).
In this context, understanding the evolution of virtual surgical planning and critically analyzing the
The integration of artificial intelligence in Oral and Maxillofacial Surgery and Traumatology becomes relevant.
not only to keep up with technological advancements in the field, but also to establish
Clear boundaries between established applications, emerging technologies, and future perspectives.
supported by evidence-based medicine.

2. LITERATURE REVIEW

2.1 Evolution of virtual surgical planning in Oral and Maxillofacial Surgery and Traumatology

Surgical planning is one of the key steps for the success of the procedures.
in Oral and Maxillofacial Surgery and Traumatology. The predictability of treatment depends on the correct
interpretation of craniofacial anatomy, identification of structural alterations, and definition of
The most appropriate surgical strategy for each patient. Historically, these decisions were
based on clinical evaluation, two-dimensional radiographs, plaster models and
Cephalometric analyses, resources that supported the development of the specialty during
decades ago, but they presented significant limitations for representing structures.
complex three-dimensional (FONSECA, 2018; MILORO et al., 2022).
The introduction of computed tomography represented one of the major technological milestones of
This specialty allows for the volumetric visualization of craniofacial structures. Subsequently, the
The consolidation of cone-beam computed tomography (CBCT) has significantly expanded

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its use in clinical practice, especially due to the high spatial resolution for structures.
bone scans, lower radiation dose when compared to conventional medical tomography in
certain indications and greater accessibility to specialized dental services. These
These features facilitated the acquisition of high-quality three-dimensional images, which are essential for
the development of virtual surgical planning (SCARFE; FARMAN, 2008).
The evolution of computer-aided design (CAD) systems and
Computer-Aided Manufacturing (CAM) has enabled...
information obtained through tomography could be incorporated into digital environments capable of
To reproduce, with high fidelity, the individual anatomy of the patient. From this workflow, it became-
If possible, perform three-dimensional simulations, define osteotomies, and position bone segments.
Adapt fixation systems and create custom anatomical biomodels and surgical guides.
before the surgical procedure is performed (MILORO et al., 2022).
This process substantially modified the planning of different procedures of
specialty. In orthognathic surgery, the integration between computed tomography,
Intraoral scanning and virtual planning have reduced limitations inherent to other methods.
Conventional methods based on articulators and manual assembly of models. In reconstruction
mandibular, the possibility of previously simulating fibular osteotomies, adapting plates of
Reconstructing and creating individualized cutting guides increased the precision of the procedure and
It reduced the need for intraoperative adjustments. Similarly, in facial traumatology,
The three-dimensional reconstruction allowed for a better understanding of the fracture lines and positioning.
of bone fragments and the relationship between adjacent anatomical structures (JOACHIM; MILORO,
2025).
Although often associated with the latest digital technologies, the concept of planning
Virtual surgery should be understood as the result of a progressive evolution of the field itself.
Oral and maxillofacial surgery. Its consolidation does not stem exclusively from the development of
new software, but also the integration between advanced diagnostic imaging methods,
computational processing, biomedical engineering, and anatomical knowledge accumulated over time
decades of evolution in the specialty. In this context, the digital environment has become an extension
of traditional surgical planning, offering greater analytical capacity without replacing the...
Biological and surgical principles that underpin clinical practice.
The advances observed in recent years have also favored the expansion of additive manufacturing in
Oral and Maxillofacial Surgery and Traumatology. Three-dimensional biomodels have begun to be used.
for anatomical study, team training, reconstruction planning and communication with
patients. In parallel, customized surgical guides and implants specific to each patient.

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(patient-specific implants – PSI) have increased the accuracy of transferring virtual planning to the operating field, reducing discrepancies between preoperative simulation and surgical execution (MARTELLI JÚNIOR; MARTELLI, 2011; JOACHIM; MILORO, 2025).

Despite these advances, the literature demonstrates that the benefits of virtual surgical planning... They vary according to the clinical indication. The strongest evidence focuses on surgery. orthognathic surgery, in microvascularized mandibular reconstruction and in reconstructive procedures. complex. In other applications, although initial results are promising, there are still... The need for prospective multicenter studies that allow for the standardization of protocols and evaluation. long-term clinical outcomes (JOACHIM; MILORO, 2025).

2.2 Fundamentals of digital workflow: CAD/CAM, 3D printing and biomodels

Virtual surgical planning is based on the integration of different digital technologies. which work in a complementary way. Among them, CAD/CAM systems form the basis for acquisition, processing and conversion of medical images into three-dimensional models capable of To represent, with high precision, the craniofacial anatomy of the patient. Initially developed Originally designed for industrial applications, these systems began to be incorporated into the healthcare field starting in... 1990s, following the evolution of diagnostic imaging methods and capabilities Computational resources available for processing three-dimensional files.

In the contemporary digital workflow, images obtained by computed tomography or CBCT are converted into digital models using specific segmentation software. This step It allows for the isolation of anatomical structures of interest, the reconstruction of three-dimensional surfaces, and the performance of other techniques. measurements with a high degree of precision. From this information, the surgeon can simulate Osteotomies, repositioning bone segments, planning reconstructions, and evaluating different strategies. pre-operative procedures before surgery.

Additive manufacturing represents the next step in this process. Unlike the methods conventional machining methods, in which material is progressively removed, the printing Three-dimensional modeling relies on the successive deposition of layers, allowing the production of biomodels. Anatomical models, surgical guides, and customized components directly from the planning stage. digital. This technology has significantly reduced the time between virtual planning and its implementation. clinical application, making it possible to reproduce complex anatomical structures with high fidelity (MARTELLI JÚNIOR; MARTELLI, 2011).

In addition to their direct application in surgical planning, three-dimensional biomodels have become... to play a relevant role in teaching, in communication between multidisciplinary teams and in

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Patient guidance. The possibility of manipulating physical replicas of craniofacial structures.
It facilitates the understanding of individual anatomy, promotes interdisciplinary planning, and contributes
for greater predictability in highly complex procedures.
Although the development of these technologies has significantly expanded the possibilities
In the field of specialized therapies, their effectiveness remains directly related to the quality of the...
The acquired images, the accuracy of the segmentation processes, and the correct clinical interpretation all contribute to this.
performed by the surgeon. Thus, the digital workflow should be understood as a support tool for
planning, whose efficiency depends on the integration between technological resources and experience.
professional, and not as an automated process independent of clinical judgment.

2.3 Artificial intelligence applied to surgical planning

The incorporation of artificial intelligence (AI) into surgical planning represents an evolution.
The natural progression of the digital workflow developed in recent decades in Surgery and Traumatology.
Oral and Maxillofacial Surgery. Unlike computed tomography, which allows for three-dimensional reconstruction.
or CAD/CAM systems, which introduced new ways of acquiring and manipulating images,
AI began to act on already available data, automating analytical processes and reducing...
operational steps and providing support for clinical decision-making (DANG et al., 2025).
In the context of healthcare, artificial intelligence encompasses a set of computational methods.
capable of performing tasks traditionally dependent on human interpretation, including
pattern recognition, image classification, anatomical segmentation and construction of
Predictive models. Among their different approaches, machine learning ...
And, more recently, deep learning *has* become one of the most popular techniques.
employed in research in oral and maxillofacial surgery, mainly due to their high capacity for
to process large volumes of medical images and identify complex relationships between variables.
anatomical (TOPOL, 2019).
Machine learning is based on training algorithms using datasets.
previously labeled, allowing the system to identify statistical patterns and make predictions.
without the need for specific programming for each situation. Deep learning, on the other hand,
It uses artificial neural networks composed of multiple processing layers, capable of extracting...
This automatically enables the training of relevant image features.
The architecture significantly reduced the reliance on manual attribute selection and expanded the
performance of algorithms in tasks related to image diagnosis (GOODFELLOW;
(BENGIO; COURVILLE, 2016).

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In Oral and Maxillofacial Surgery and Traumatology, the most studied applications focus on
Automatic segmentation of anatomical structures in computed tomography scans and
Cone beam computed tomography. Precise identification of the mandible, maxilla, canal.
The examination of the mandible, condyles, orbits, impacted teeth, and dental structures represents a fundamental step.
for virtual surgical planning, especially in reconstructive procedures, surgery
Orthognathic and implant dentistry. Traditionally, this segmentation was performed manually or by
semi-automated methods, demanding considerable time from the professional and resulting in high variability.
among observers. Deep learning-based models have begun to demonstrate performance.
consisting of automating these tasks, reducing the time required for processing them.
images and increasing the standardization of the digital workflow (DANG et al., 2025).
Another growing application relates to supporting the diagnosis and classification of alterations.
Craniofacial fractures. Recent studies describe the use of algorithms capable of identifying fractures.
mandibular structures, locate impacted third molars, detect bone lesions, and recognize alterations in the...
Temporomandibular joint diagnosis is based on radiographic and tomographic examinations. Although these
Although the results may be promising, most research remains limited to studies.
Retrospective studies conducted on specific databases still show a lack of validation.
prospective multicenter studies that allow confirmation of its clinical applicability in different
populations (DANG et al., 2025).
Artificial intelligence is also being used in the surgical planning itself.
to automate steps traditionally performed by the surgeon. Experimental systems are
capable of suggesting osteotomy lines, assisting in the virtual repositioning of bone segments,
To estimate reconstructive volumes and optimize implant placement based on parameters.
previously established anatomical features. Despite the technological advances observed in these models, the
Available evidence suggests that such tools should be interpreted as support systems.
to planning and not as autonomous mechanisms for therapeutic decision-making. The definition of the technique
surgical, functional analysis, and clinical judgment remain dependent on the experience of the
specialist, especially in the face of complex anatomical situations or systemic conditions that
escape the currently available computational models (JOACHIM; MILORO, 2025).
Another field of investigation involves the development of predictive models aimed at
Estimation of clinical outcomes. Algorithms trained with clinical, radiographic and...
Surgical methods have been used to predict postoperative stability and the occurrence of complications.
The need for additional grafts and the behavior of bone reconstructions over time.
Although these applications show potential to contribute to the individualization of treatment,
The literature still lacks prospective studies capable of demonstrating a consistent impact on

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Relevant clinical indicators, such as reduction of complications, functional improvement or increase in survival of complex reconstructions (DANG et al., 2025; JOACHIM; MILORO, 2025).

Thus, the main contribution of artificial intelligence to Surgery and Traumatology Oral and maxillofacial surgery does not aim to replace the surgeon, but to increase the efficiency of the workflow. digital. The automation of repetitive tasks, the standardization of image processing, and the Integrating large volumes of information allows for the optimization of pre-operative planning and reduce the time spent on operational steps. However, clinical interpretation, the definition of Therapeutic strategy and responsibility for decisions remain exclusively the responsibility of the individual. human beings, while preserving the surgeon's central role in the care process.

2.4 Current scientific evidence and limitations

The exponential growth of publications on artificial intelligence in the last decade was not accompanied by a proportional expansion of high-level evidence clinical studies. Reviews Recent studies show that a large part of the available literature consists of research. retrospective studies, methodological studies, and computational validations performed in environments Experimental studies. Prospective clinical trials, multicenter studies, and comparative analyses. Studies involving clinical outcomes remain relatively scarce, limiting the extrapolation of... results for clinical practice (DANG et al., 2025).

Another widely discussed aspect concerns the quality of the databases used for Training the algorithms. Deep learning systems depend on thousands of images. previously classified, segmented, and validated by experts. When these databases They consist of tests originating from a single institution, acquired using equipment. similar to or representative of specific populations, there is a risk of reduced performance. when the algorithm is applied in different clinical scenarios. This limitation, known as low The ability to generalize constitutes one of the main challenges for the routine implementation of Artificial intelligence in different health services.

Methodological heterogeneity also makes it difficult to compare studies. Differences related to image acquisition protocols, software used, and architectures of Neural networks, the validation criteria, and the statistical indicators employed prevent, in In many cases, direct comparisons between independent investigations are necessary. Consequently, results considered excellent in a given study are not always... These findings can be replicated by other research groups.

Issues related to the transparency of algorithms represent another topic of growing interest.

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Scientific. Many deep learning models operate as low-level systems.
interpretability, producing results without the user being able to fully understand what they are.
parameters influenced a particular computational decision. This characteristic stimulated the
development of what is called Explainable Artificial Intelligence *(Explainable Artificial Intelligence – XAI),* whose objective is to increase the transparency of the models and allow for a greater understanding of decision-making process by health professionals (TOPOL, 2019).

From an ethical standpoint, the use of artificial intelligence also poses related challenges.
to data privacy, the security of clinical information, and professional responsibility in relation to
of decisions supported by computer systems. The proper anonymization of exams, the
compliance with data protection laws and a clear definition of responsibilities between
Developers and healthcare professionals are indispensable aspects for incorporation.
ensuring the safety of these technologies in clinical practice.

For this reason, contemporary literature converges on a common understanding: intelligence.
Artificial intelligence should be understood as a tool to support surgical planning, capable of...
To increase the efficiency of the digital workflow, but unable to replace critical analysis and clinical experience.
and the professional judgment of the oral and maxillofacial surgeon. Technological advancement expands the diagnostic and therapeutic possibilities of the specialty, however its use remains
subject to the principles of evidence-based medicine, professional ethics and
Individualization of care.

3 CLINICAL APPLICATIONS OF VIRTUAL SURGICAL PLANNING AND ARTIFICIAL INTELLIGENCE

3.1 Orthognathic surgery

Orthognathic surgery was one of the first areas of Oral and Maxillofacial Surgery and Traumatology to...
to systematically incorporate virtual surgical planning. For decades, planning
It was based on two-dimensional cephalometric tracings and mounting models on articulators.
Semi-adjustable and manual fabrication of occlusal guides. Although these methods have provided
Despite satisfactory clinical results, limitations related to the reproduction of anatomy were present.
three-dimensional, especially in complex facial deformities and skeletal asymmetries (BELL;
PROFFIT; WHITE, 1980; MILORO et al., 2022).

The introduction of virtual planning has changed this scenario by allowing integration between
Computed tomography, intraoral scanning, and digital models of the dental arches. This

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The combination enables the three-dimensional reconstruction of the craniofacial complex, the simulation of Osteotomies and predicting the final positioning of bone segments before the procedure. surgical. As a consequence, procedures that previously depended on successive steps Laboratory procedures are now planned in a digital environment, reducing potential sources of error. accumulated throughout the process (JOACHIM; MILORO, 2025).

Another important advance was the progressive replacement of manually made guides with Guides produced by additive manufacturing based on virtual planning. These devices allow greater fidelity between preoperative simulation and intraoperative execution, contributing to the Reproducibility of planned movements and reduced need for adjustments during surgery. (MILORO et al., 2022).

Comparative studies suggest that virtual planning offers high accuracy in reproduction. of jaw movements, especially when associated with intraoral scanning and Digital fabrication of surgical guides. However, the literature also demonstrates that the magnitude The benefit varies depending on the complexity of the deformity, the team's experience, and the quality of the service. of the digital workflow employed. Therefore, virtual planning should be understood as a It is an instrument to increase surgical predictability, and not an isolated factor capable of guaranteeing it. better clinical results (JOACHIM; MILORO, 2025).

In recent years, artificial intelligence algorithms have been incorporated into some stages. of this process. Among its applications, the automatic segmentation of bone structures stands out, the Identification of cephalometric points and alignment between tomographic examinations and digital models. of the arcades. Although these tools reduce the time needed for planning preparation, its use remains primarily restricted to information processing, without replacing the definition of the surgical strategy or functional analysis performed by the specialist (DANG et al., 2025).

3.2 Facial Traumatology

Treatment of facial fractures requires precise restoration of skeletal anatomy and stability of the... Bone segments and functional recovery of the stomatognathic system. In high-risk injuries. complexity, especially those involving multiple facial bones, the interpretation of Anatomy can become difficult to visualize using only two-dimensional images, making planning challenging. Three-dimensional imaging is a resource of great clinical relevance (FONSECA, 2018).

Virtual reconstruction allows you to simultaneously visualize all bone fragments, simulating anatomical reductions and anticipating difficulties related to surgical access and adaptation of the

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fixation systems. In orbital fractures, for example, the use of the contralateral side as
Anatomical reference facilitates more precise reconstructions of orbital volume. In fractures
In panfacial reconstruction, three-dimensional reconstruction helps define the reduction and stabilization sequence.
of the different bone segments, contributing to the restoration of width, projection and height
facial (ELLIS III; ZIDE, 2006).

Three-dimensional printing has also come to play an important role in this context.
Biomodels obtained from computed tomography allow for pre-molding of titanium plates before...
surgery, reducing intraoperative manipulations and promoting more precise adaptation to
bone contours. In selected cases, patient - specific implants.
Implants can also be manufactured using virtual planning, especially in
complex orbital reconstructions or extensive craniofacial defects (JOACHIM; MILORO, 2025).

The applications of artificial intelligence in facial traumatology focus primarily on
diagnostic phase. Deep learning models have been demonstrating promising performance in
Automatic detection of mandibular, zygomatic, and orbital fractures in computed tomography scans.
Despite the high sensitivity rates reported in experimental studies, the literature still...
It recommends caution regarding its routine incorporation, since most algorithms
remains dependent on retrospective validations performed on limited databases (DANG).
et al., 2025).

From a clinical perspective, the main contribution of these technologies lies in expanding the capacity
The surgeon's analytical skills. The interpretation of fracture lines, the choice of access route, the indication.
The method of fixation and the conduct of treatment continue to be decisions based on...
professional experience, in clinical assessment and in the consolidated biomechanical principles of
Oral and maxillofacial traumatology (ELLIS III; GHALI; LARSEN; WAITE, 2012).

3.3 Mandibular reconstruction

Mandibular reconstruction is one of the most well-established applications of surgical planning.
Virtual therapy in Oral and Maxillofacial Surgery and Traumatology. Patients undergoing tumor resection,
Extensive trauma, osteonecrosis of the jaws, or sequelae of infections can present with tooth loss.
significant bony fractures, the treatment of which requires simultaneous restoration of mandibular continuity,
of occlusion, masticatory function and facial aesthetics (HIDALGO, 1989).

Traditionally, the adaptation of bone grafts and reconstruction plates was performed during
the surgical act, increasing the surgical time and the technical complexity of the procedure.
The development of virtual planning has made it possible to anticipate these steps through simulation.

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three-dimensional osteotomies, prior definition of the positioning of bone segments and of
Manufacturing of customized surgical guides.
Reconstruction with a free fibula flap represents one of the main examples of this evolution.
Virtual planning allows you to determine in advance the number of bone segments needed, the
length of each osteotomy, the final position of the graft, and the adaptation of the reconstruction plates,
reducing the need for intraoperative adjustments and promoting greater anatomical predictability.
(JOACHIM; MILORO, 2025).
In addition to cutting guides, the use of custom-made plates produced by CAD/CAM technologies is also common.
It is being progressively incorporated into specialized centers. These devices feature
precise adaptation to the previously planned anatomy and can reduce deformities resulting from
Manual contouring of conventional plates. However, their high cost and the need for
Specialized technological infrastructure still represents a limiting factor for widespread adoption.
dissemination of this approach.
Recent reviews demonstrate that virtual planning provides consistent benefits.
related to the geometric precision of the reconstruction and the standardization of the surgical procedure.
However, there are still limitations regarding the demonstration of clinical superiority in outcomes.
long-term factors, such as functional recovery, quality of life, and graft survival,
highlighting the need for prospective multicenter studies capable of reducing the
methodological heterogeneity observed in the literature (JOACHIM; MILORO, 2025).

3.4 Implantology and bone reconstructions

Implantology was one of the areas most impacted by the incorporation of digital workflow. The association
between cone beam computed tomography, intraoral scanning and software of
Three-dimensional planning made it possible to integrate anatomical, prosthetic, and functional information.
in a single virtual environment, allowing the implant placement to be defined.
prior to surgery (MISCH, 2015; MILORO et al., 2022).
Guided prosthetic planning has become one of the main advances in this process.
Instead of considering only bone availability, implant placement became...
planned in accordance with future prosthetic rehabilitation, respecting important anatomical structures,
biomechanical characteristics and aesthetic requirements. As a consequence, a greater [observation] was observed.
Surgical predictability and reduced need for corrections during the procedure.
In this context, artificial intelligence has been applied primarily to automatic segmentation.
from tomographic examinations, identification of the mandibular canal, recognition of anatomical structures

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and organization of the digital workflow. Although these applications reduce the time required for the planning, the available evidence is still insufficient to state that the algorithms promote better clinical outcomes when compared to conventional planning. conducted by experienced professionals (DANG et al., 2025).

Thus, the most consistent contribution of artificial intelligence in implant dentistry remains... related to optimizing workflow, without replacing clinical judgment in defining the surgical strategy.

4. DISCUSSION

The evolution of virtual surgical planning represents one of the most significant transformations in... Oral and Maxillofacial Surgery and Traumatology in recent decades: The incorporation of computed tomography. Computerized technology, CAD/CAM systems, and additive manufacturing have changed the way... Complex procedures are planned, allowing for greater individualization of treatment and better... Integration between diagnosis, planning and surgical execution (JOACHIM; MILORO, 2025).

Although the benefits related to anatomical accuracy and planning predictability are Widely described, their magnitude varies according to the clinical indication. The strongest evidence They focus on orthognathic surgery and mandibular reconstruction with flaps. microvascularized areas, where virtual planning has demonstrated high reproducibility and greater correspondence between the pre-operative simulation and the result obtained during surgery. In In other applications, such as facial traumatology and implantology, the results remain Promising, but still dependent on prospective studies capable of establishing protocols. standardized methods and evaluate long-term clinical outcomes.

A similar situation occurs with artificial intelligence. Despite the significant growth of In scientific publications, most studies focus on automating segmentation. Anatomical studies, image classification, and the development of predictive models. Few investigations. They demonstrated a direct impact on clinical indicators, such as reduction of complications, improvement functional or increased survival of complex reconstructions. In this way, the benefits Currently observed trends focus on optimizing digital workflow and reducing the time spent on digital workflow. to planning, and not to replace clinical decision-making (DANG et al., 2025).

Another aspect frequently highlighted refers to the methodological quality of the research. predominance of retrospective studies, small sample sizes, lack of external validation, and high Heterogeneity among algorithms makes it difficult to compare results and limits their generalization. for different populations and services. In addition, aspects related to the transparency of the models.

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Computational issues, data protection, and professional responsibility remain central themes.
for the safe incorporation of these technologies into healthcare practice.
In this context, artificial intelligence should be understood as a complementary tool to
Surgical planning, capable of increasing operational efficiency and supporting information analysis.
available, but without replacing anatomical knowledge, clinical experience, and judgment.
surgeon. Technological advancements are expanding the possibilities of the specialty; however, its use
It must remain grounded in the principles of evidence-based medicine and evaluation.
individualized for each patient.

CONCLUSION

Virtual surgical planning has become established as one of the main innovations incorporated into
Oral and Maxillofacial Surgery and Traumatology in recent decades, promoting changes.
Significant in the way complex procedures are planned and executed. Integration
including three-dimensional imaging exams, CAD/CAM systems, biomodels, surgical guides
Customized and additive manufacturing technologies have increased operational predictability and favored...
greater precision in the execution of surgical techniques has contributed to an increasingly more...
Individualized treatment. Available scientific evidence demonstrates benefits.
consistent, especially in orthognathic surgery, mandibular reconstruction, facial traumatology and
implantology, areas in which the digital workflow has come to play a significant role in reducing
operational variability and improvement in preoperative planning.
The incorporation of artificial intelligence represents a new stage in this technological evolution. Its
The main contribution, to date, focuses on automating tasks related to
image processing, anatomical segmentation, digital workflow organization and support for
surgical planning. However, the literature reviewed shows that these applications still
They have significant limitations, especially regarding clinical validation and standardization.
methodological and generalizability of algorithms for different populations and care settings.
Although initial results are promising, evidence capable of concluding this remains scarce.
demonstrate a consistent impact on long-term clinical outcomes, reinforcing the need for
prospective, multicenter, and methodologically more robust studies.
Another aspect that deserves attention relates to ethical, regulatory, and operational challenges.
associated with the incorporation of these technologies into clinical practice. Issues related to quality.
from the databases used to train the algorithms, to the transparency of the models.
computational technologies, the protection of patient information, and professional responsibility in the face of

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Decisions supported by intelligent systems should keep pace with technological advancements.
specialty. The adoption of these tools requires not only adequate infrastructure, but also
professional training and protocols that ensure its safe and reproducible use and
based on scientific evidence.

In this context, it becomes evident that artificial intelligence should not be understood as
not a substitute for clinical experience, but a complementary resource capable of increasing efficiency.
surgical planning and providing support for decision-making. The interpretation of information,
The definition of the therapeutic strategy and the conduct of the treatment remain dependent on
technical knowledge, the surgeon's experience, and the individualized assessment of each patient,
principles that remain the cornerstones of Oral and Maxillofacial Surgery and Traumatology
contemporary.

Finally, it is concluded that the future of the specialty will be determined by a balanced integration between
Technological innovation, scientific knowledge, and clinical experience. Continuous development of
virtual surgical planning, combined with the improvement of artificial intelligence applications,
It tends to increase the precision of procedures and strengthen increasingly personalized approaches.
However, the consolidation of these technologies will depend on the production of high-quality clinical evidence.
quality, standardization of digital protocols, and the responsible incorporation of these tools.
to clinical practice, preserving patient safety and the principles of blood-based medicine.
evidence as the basis for the practice of the oral and maxillofacial surgeon.

REFERENCES

BELL, William H.; PROFFIT, William R.; WHITE, Raymond P. *Surgical correction of dentofacial deformities.* Philadelphia: WB Saunders, 1980. 2 v.

DANG, Rushil Rajiv et al. The current landscape of artificial intelligence in oral and maxillofacial surgery: a narrative review. *Oral and Maxillofacial Surgery,* 2025.

ELLIS III, Edward; ZIDE, Michael F. *Surgical approaches to the facial skeleton.* 2nd ed. Philadelphia: Lippincott Williams & Wilkins, 2006.

FONSECA, Raymond J. (ed.). *Oral and maxillofacial surgery.* 3rd ed. St. Louis: Elsevier, 2018. 3 v.

GOODFELLOW, Ian; BENGIO, Yoshua; COURVILLE, Aaron. *Deep learning.* Cambridge: MIT Press, 2016.

HIDALGO, David A. Fibula free flap: a new method of mandible reconstruction. *Plastic and Reconstructive Surgery,* Baltimore, v. 84, no. 1, p. 71-79, 1989.

MARTELLI JÚNIOR, Hercílio; MARTELLI, Danielle Reis. Three-dimensional printing in oral and maxillofacial surgery: a literature review. *Annals of Maxillofacial Surgery,* vol. 1, no. 1, p. 67-71, 2011.

MILORO, Michael; GHALI, Gamal E.; LARSEN, Per E.; WAITE, Peter D. *Peterson's principles of oral and maxillofacial surgery.* 4th ed. Cham: Springer, 2022.

MISCH, Carl E. *Dental implant prosthetics.* 2nd ed. St. Louis: Elsevier, 2015.

SCARFE, William C.; FARMAN, Allan G. What is cone-beam CT and how does it work? *Dental Clinics of North America,* vol. 52, no. 4, p. 707-730, 2008.

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Topol, Eric. *Deep medicine: how artificial intelligence can make healthcare human again.* New York: Basic Books, 2019.

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